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THE SENSOR IMAGE SIMULATOR

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ABSTRACT

The primary objective of the digital sensor simulation investigations being conducted at the Defense Mapping Agency (DMA) is to establish an editing and analysis capability for the digital culture and terrain data bases. For purposes of quality control and data base applicability investigations, DMA has developed the Sensor Image Simulator (SIS), a very high speed data base edit station and static scene simulator that allows for interactive query and manipulation of individual features in the data base displays and/or simulated sensor scenes to determine the corresponding data base elements responsible for the simulated features. The SIS was installed at DMA in 1981, and is designed to play a key role in determining the applicability of prototype data bases for use in advanced training simulators, as well as to ensure the quality of, and coherence between, the various digital data bases prior to new data insertion into the master cartographic data base files.

THE SENSOR IMAGE SIMULATOR

INTRODUCTION

The pimary objective of the digital sensor simulation investigations being conducted at the Defense Mapping Agency (DMA) is to establish an editing and analysis capability for the digital culture and terrain data bases. These data bases are being produced by DMA to support advanced aircraft simulators by providing an improved high, medium and low level radar training capability offered by the digitally generated radar landmass images. As a result of the technology developed for the aircraft simulator support, sensor guidance reference scenes are also being generated.

In addition to radar scenes, visual and multi-sensor scenes are being digitally generated. For purposes of quality control and data base applicability investigations, DMA has developed the Sensor Image Simulator (SIS), a very high speed data base edit station and static scene simulator that allows for interactive query and manipulation of individual features in the data base displays and/or simulated sensor scenes to determine the corresponding data base elements responsible for the simulated features (see Figure 1). The SIS was installed at DMA in 1981, and is designed to play a key role in determining the applicability of prototype data bases for use in advanced training simulators, as well as to ensure insuring the quality of, and coherence between, the various digital data bases prior to new data insertion into the master cartographic data base files.

DATA BASE CONTENT

The current DMA standard production data bases (Level I) contain large area cultural information and digital terrain data sampled at a 3" interval. The cultural data consists of point, linear, and areal features described by characteristics such as surface material category, generic identification, predominant height, structure density, and percentages of roof and tree cover. The cultural data is in lineal (planimetric boundary) format and, although feature sizes may vary depending upon local circumstances, reflects a resolution on the order of 500 feet. Smaller features are aggregated into homogeneous features described by predominant characteristics. The current high resolution (Level II) data bases contain small area cultural information and digital terrain elevation data sampled at a 1" interval. This translates to a resolution of about 100 feet, with smaller features aggregated. Detailed information is available in "Product Specifications for Digital Landmass System (DLMS) Data Base" (1).

The terrain elevation data is produced by contour digitization from charts or directly from stereo pairs of photographs using advanced analytical stereoplotters. The cultural data is produced from both charts and photographs with a much higher level of manual effort required in order to perform the complex feature analysis. Because of the labor intensive nature of the task, the production of Level II cultural data ranges from 10 to 50 times the production cost of Level I data, depending upon the area. The current Level I data base program covers roughly 24 million square nautical miles, with estimated data base completion dates in the 1985 to 1995 time period. Level II data is programmed only for small selected areas of interest.

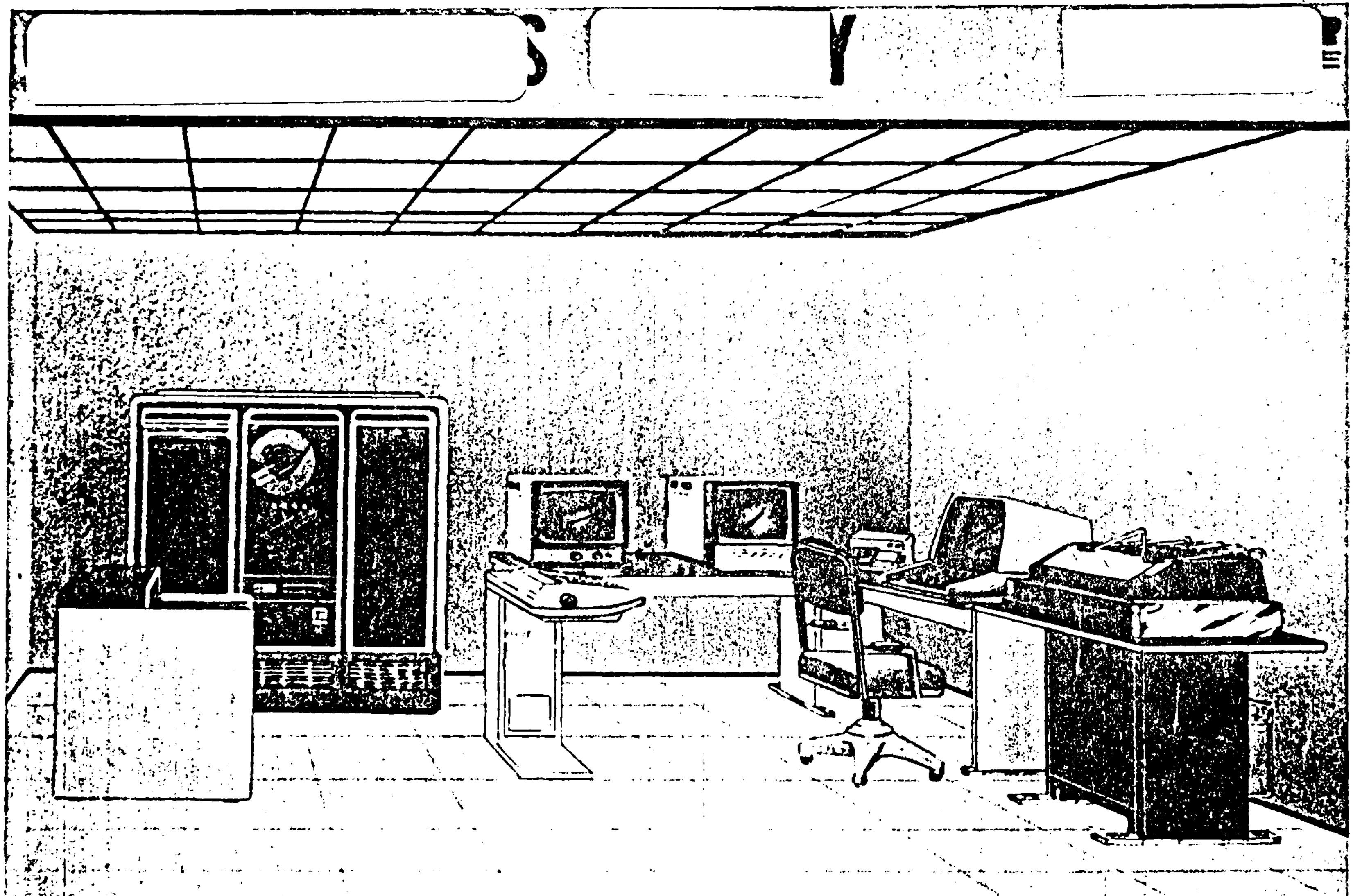

Figure 1 The Sensor Image Simulator

The DLMS data bases have been shown to be adequate for support of long and medium range radar simulation, and for short range radar simulation where Level II data is available. In addition, these data bases have shown some applicability for multi-sensor simulation (3, 4).

THE SENSE SYSTEM

SENSE (2) is a software package developed for sensor simulation investigations by the Defense Mapping Agency Aerospace Center. A powerful simulation tool, it runs in batch mode on one of DMA's Univac 1100 series computers.

The SENSE process begins by defining the area for which an on-line data base is to be constructed. Either center coordinates and areal extent or limiting geographic boundaries may be entered. In both cases, output spacing is specified. Transformation to a local coordinate frame for a number of point coordinates may also be specified.

The second step in the process is concerned with transforming the off-line data base to on-line format. Two formats for input terrain (i.e., DLMS or DMA standard) may be accepted. The latitude and longitude boundaries of the area are also input. For the input cultural feature files, a variety of options may be exercised to define which manuscripts or features are to be utilized. Synthetic feature breakup of the data base in accordance with feature characteristics may also be specified. Output displays for terrain, culture or merged data may be generated for the line printer or an Optronics film recorder. The principal output of this step, however, is the on-line data base in blocked matrix format.

Once generated, the on-line data base may be processed by four separate program structures; (a) the data base may be reblocked to provide an on-line data base of different spacing, (b) it may be input to a plot module to provide a variety of plot types, (c) it may be unblocked to provide a single large data base, and (d) it may be used as the input for sensor simulation software.

For sensor simulation, considerable variation in the SENSE output is possible by appropriate selection of input variables. These include:

1. Input data base characteristics and portion utilized.

2. Sensor coverage and characteristics (type, receiver characteristics, antenna pattern, etc.).

3. Constants defining sensor position and the projection coordinate transform.

4. Weather options and atmospheric variables.

5. Output plot options.

A number of deficiencies result from the computer environment in which SENSE operates:

1. DMA's 1100 Series computers cannot be totally dedicated to quality control/validation.

2. The system is not interactive; editing is therefore not feasible nor are the results of processing stages immediately available.

3. Both the off-line to on-line transformations and sensor simulation tasks are slow (typically 10-30 minutes).

4. Program structures are not optimized.

THE SIS CONCEPT

The natural evolution of sensor simulation at DMA led to the design and fabrication of the Sensor Image Simulator (SIS), a dedicated minicomputer-based image processing system capable of performing simulations in an interactive mode.

The SIS brings together, in a self-contained integrated hardware/software facility, a significant capability to evaluate the DLMS data base. All operations are conducted under interactive control. Both the software structure and operations sequence reflect a top-down implementation philosophy wherein principal control functions are resident at the top of the hierarchy and functions concerned with processing individual data elements (I/O, computation, etc.) are at the lowest. The system is implemented in such a fashion that future changes in processing can be accomplished at the highest level of system software support.

Basic input data to the system consists of the off-line DLMS data base tapes and operator commands specifying which tape data available is to be transferred to secondary storage (the system disk). Editing commands revising the off-line data (on secondary storage) may also be utilized, and a designated portion of the changed data may be transferred back to tape, with appropriate optional diagnostics documenting transfers in either direction.

Once resident on the system disk, any portion of the off-line data may be transformed into a viewable on-line format. In order to permit viewing of the data base, a sensor module must be specified to transform feature data to sensor-related quantities (reflectivity, albedo, etc.). The local coordinate transform may also be specified.

The on-line version is constructed in such a fashion that the operator may easily interrogate and change the data base and relate these revisions to the off-line data base.

The final step of processing under normal interactive control is concerned with sensor simulation. Two types of scenes are generated during this stage. The first of these (selectable by the operator) is the perspective view. This option permits selection of position and line of sight for mapping the (three dimensional) data base into the observer's image display coordinate frame. The second type of scene generated is the sensor display. Data used is common to that generated for the perspective view. Modifications which may be introduced into the sensor display include sensor parameters (e.g., beam error) and sensor display variations (e.g., gain). An important characteristic of the display transform is that the operator can easily establish the relationship between the sensor display and the on-line data base.

In addition to the processing stages (including editing), normally under operator control, software development and maintenance is also an interactive function using the system's text editor and FORTRAN compiler.

SIS OPERATIONS

The Sensor Image Simulator performs five major functions:

1. Digital data base file input and output.

The capability of loading operator designated sections of the DLMS off-line data base (both terrain and/or culture files) onto the system secondary storage device is provided. The capability also exists to off-load such data (including modifications) onto tape in DLMS standard format. A line printer listing documenting the loading process may (at the operators discretion) also be provided.

2. Off-Line to On-Line Transformation.

The SIS system performs the processes (coordinate transformation, area fill, etc.) necessary to transform the off-line DLMS data base, stored as described above, into an on-line format capable of being viewed, and modified by the operator, as well as used in subsequent stages of processing. The transformation is accomplished in approximately two minutes for a $1^{\circ} \times 1^{\circ}$ Level I area.

3. Sensor Simulation.

The SIS facility generates simulated sensor displays using the on-line data base. The system is structured such that data from intermediate stages of processing is available for viewing and/or the introduction of operator controlled variations.

4. Interactive data base editing.

As a quality control tool for DLMS, the SIS provides the operator with the ability to both define the characteristics of and modify the three principal data structures present (off-line DLMS, on-line DLMS, and the sensor display).

5. Software Development and Maintenance.

In order to provide for the future evolution of sensor simulation, the SIS is structured to permit changes in function by modification of the appropriate software module/sub-modules affected. Whole modules may also be inserted or removed. This allows for variation in future data base formats. The commercially supported real time multi-tasking operating system supports software development via system utilities (text editor, assembler and FORTRAN compiler).

SIS HARDWARE

The SIS hardware may be discussed in four general areas (6).

1. Host Computer.

The host computer is a Data General "Eclipse" S/250 with integral array and floating point processors.

2. Soft-copy Image Display Subsystem.

Data base and sensor images are displayed on either the Aydin 8026 Color Monitor or the Aydin 8037 Monochrome Monitor. Both units display 1024 x 1024 images and are controlled by the Aydin 5116 Display Editor Keyboard and Joystick and the Aydin 5216 Display Computer. Graphic data may be displayed on the Tektronix 4006-1 Graphic Display Terminal.

3. Hard-copy Image Display Subsystem.

Color hardcopy images are obtained from the Matrix Instruments 4007 Color Graphic Camera yielding both 8 in. x 10 in. instant copy and 35mm film output. For quick inexpensive monochrome copy, the Tektronix 4634 Video Hard Copy Unit is used.

4. Peripheral Devices.

The SIS configuration is completed by the following peripheral devices:

a. Analogic AP400 Array Processor.

b. Data General 6026 1600/800 FPI Tape Unit.

c. AVIV TFS 706-125 6250/1600/800 FPI Tape Unit.

d. Data General 6061 190 MB Disc Storage Unit.

e. Data General 6070 20 MB Disc Storage Unit.

f. Data General 6040 Terminal Printer.

g. Teletype 40 Line Printer.

SIS SOFTWARE ARCHITECTURE

The development of software for SIS was determined by the following requirements:

1. The software structure must be user programmable to support changing data base and sensor support requirements.

2. The throughput capabilities of the hardware elements of the system must be accessible at the highest levels of software development.

3. User interaction with the system must be accomplished in such a fashion that personnel not intimately familiar with digital processing are capable of utilizing its functions.

Orderly development of SIS software was accomplished via a top-down implementation philosophy wherein the software structure is strongly reflected in the operations sequence. All application functions are accomplished via interactive control. The hierarchial system structure guides the operator in defining a processing requirement with an increasing level of detail until all necessary parametric entries are available. The defined processing then takes place, after which the operator is given the choice of returning to a higher level in the system or repeating the processing sequence with a redefined set of parameters.

Accommodating a variety of users within the system has led to the development of entry and menu display software which combines fail-safe operation and comprehensive

explanation capabilities with features designed to reduce redundancy for highly knowledgeable personnel. Although the principal application language is FORTRAN, the decoding of operator entries is handled via application routines rather than standard FORTRAN formatted I/O. Thus, the detection of errors may be handled by the application program, rather than at the systems level thereby avoiding execution abort due to input error. In addition, the operator is given the opportunity to revise entries before proceeding (via a simple carriage return on the system console). At the level where a large number of entries (each with a variety of possible settings) is required, submenus for each parameter are not initially displayed unless requested by the operator (by simply entering the parameter number). In addition, an entry of several parameter values may be made simultaneously with repeated menu displays. At the same time, a detailed explanation of possible entry values for various parameters is available directly at the system console via a simple procedure for each level of the process.

CONCLUSIONS

The Sensor Image Simulator is designed to play a key role in both the requirements analysis and quality control of the DLMS data bases being produced by DMA. Current investigations are allowing for the development of production quality control scenarios to maximize the capabilities offered by the SIS. The usefulness of SIS is being expanded through the development of new sensor modules designed to determine data base requirements for a variety of sensors.

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